

## Estimation of Effect Factors for application to marine eutrophication in LCIA

**Cosme, Nuno Miguel Dias; Hauschild, Michael Zwicky**

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# Estimation of Effect Factors for application to marine eutrophication in LCIA



*Session: Advancements in life cycle impact assessment and footprint method development (II)*  
*Tue May 13<sup>th</sup> 2014 – Shanghai Room*

**Nuno Cosme and Michael Z. Hauschild**

[nmdc@dtu.dk](mailto:nmdc@dtu.dk)

*PhD student*

**Quantitative Sustainability Assessment**  
Department of Management Engineering

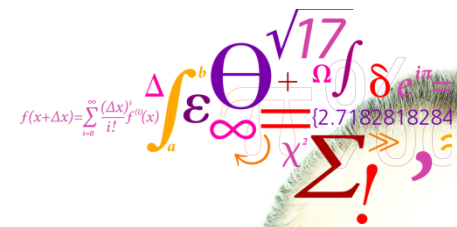


OTTO MØNSTEDS FOND

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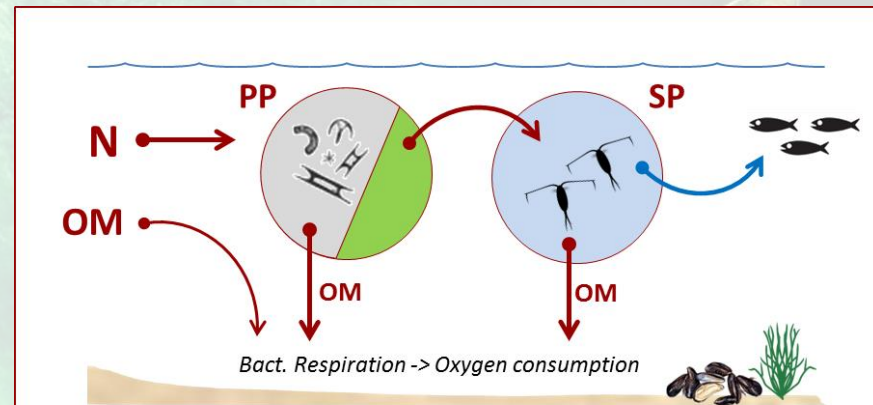


# Marine eutrophication

Ecosystem response to an excessive input of nutrients promoting an increase of primary production

Also from emissions of organic matter (e.g. river transport, sewage discharge)

Results in excessive oxygen depletion and impacts on biota, ecosystem and (socio)economy





# Characterisation modelling

LCIA -> Characterisation Factors (**CF**) to translate emissions to potential impacts

$$CF = FF * XF * EF$$

Factors:

**Fate (FF)**: how much N available ?

**Exposure (XF)**: how N originates O<sub>2</sub> depletion ?

**Effect (EF)**: benchmarks the impacts of oxygen depletion on biota

Damage dimension: species affected/  
disappeared (i.e. loss of biodiversity)





# Species sensitivity to hypoxia

The dataset:

## PNAS Thresholds of hypoxia for marine biodiversity

Raquel Vaquer-Sunyer\* and Carlos M. Duarte

15452–15457 | PNAS | October 7, 2008 | vol. 105 | no. 40

- Data of sublethal threshold concentration ( $\text{mgO}_2/\text{L}$ ) for 71 marine species
- 58 relevant species: only benthic, demersal and benthopelagic
- Fish (12), crustaceans (13), molluscs (7), echinoderms (7), annelids (7), cnidarians (11), plants (1)





## Endpoints tested

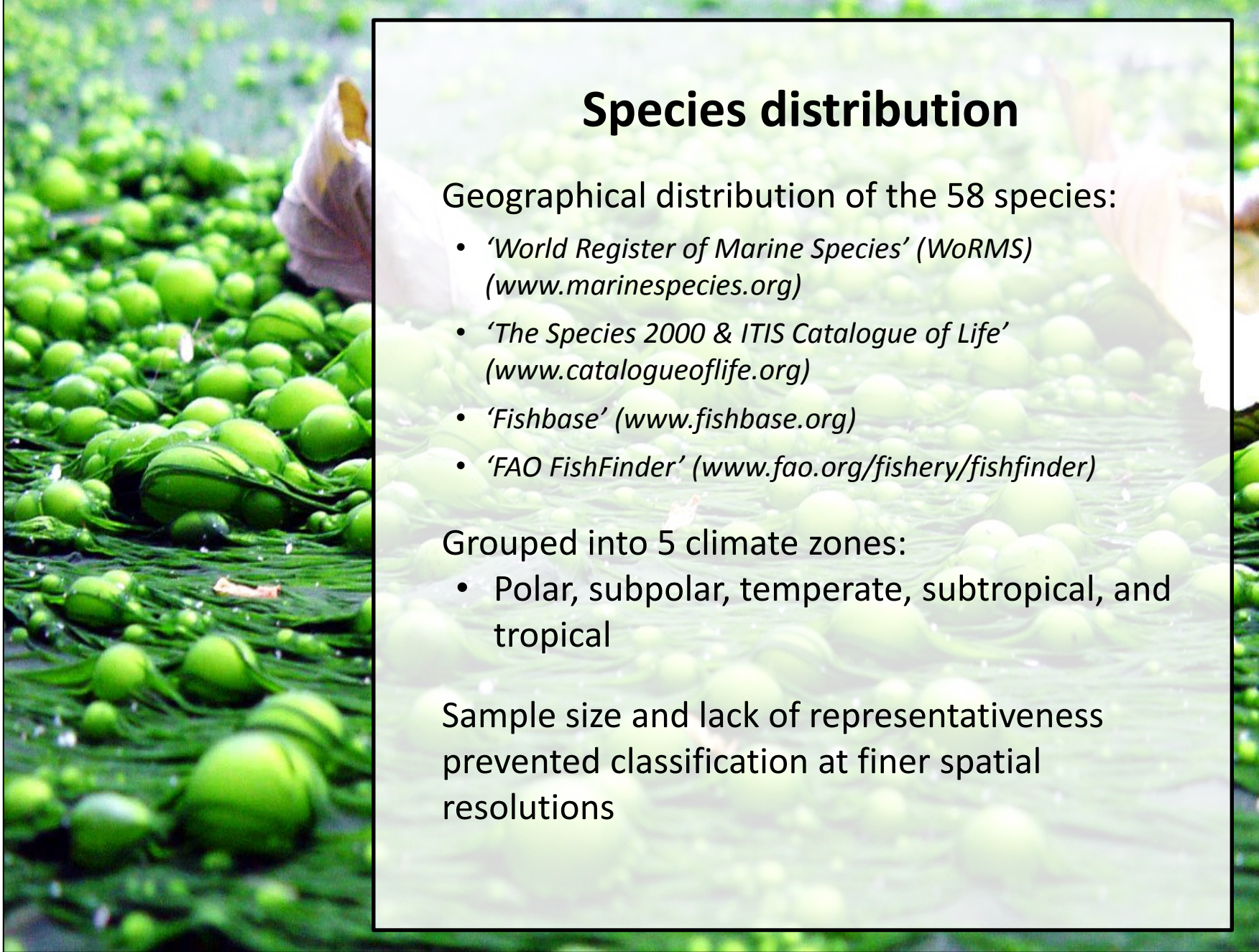
Sub-lethal responses:

- **Behavioural** level  
(e.g. avoidance strategies)
- **Physiological** level  
(e.g. limiting growth, activity and respiration rates)
- *(NOT) **Ecological** level*  
*(e.g. altering structure, function, and services of benthic communities)*

Sensitivity to dissolved oxygen levels = **LOEL**,  
*Lowest Observed Effect Level*

How to extrapolate individual species  
sensitivity to ecosystem's?





## Species distribution

Geographical distribution of the 58 species:

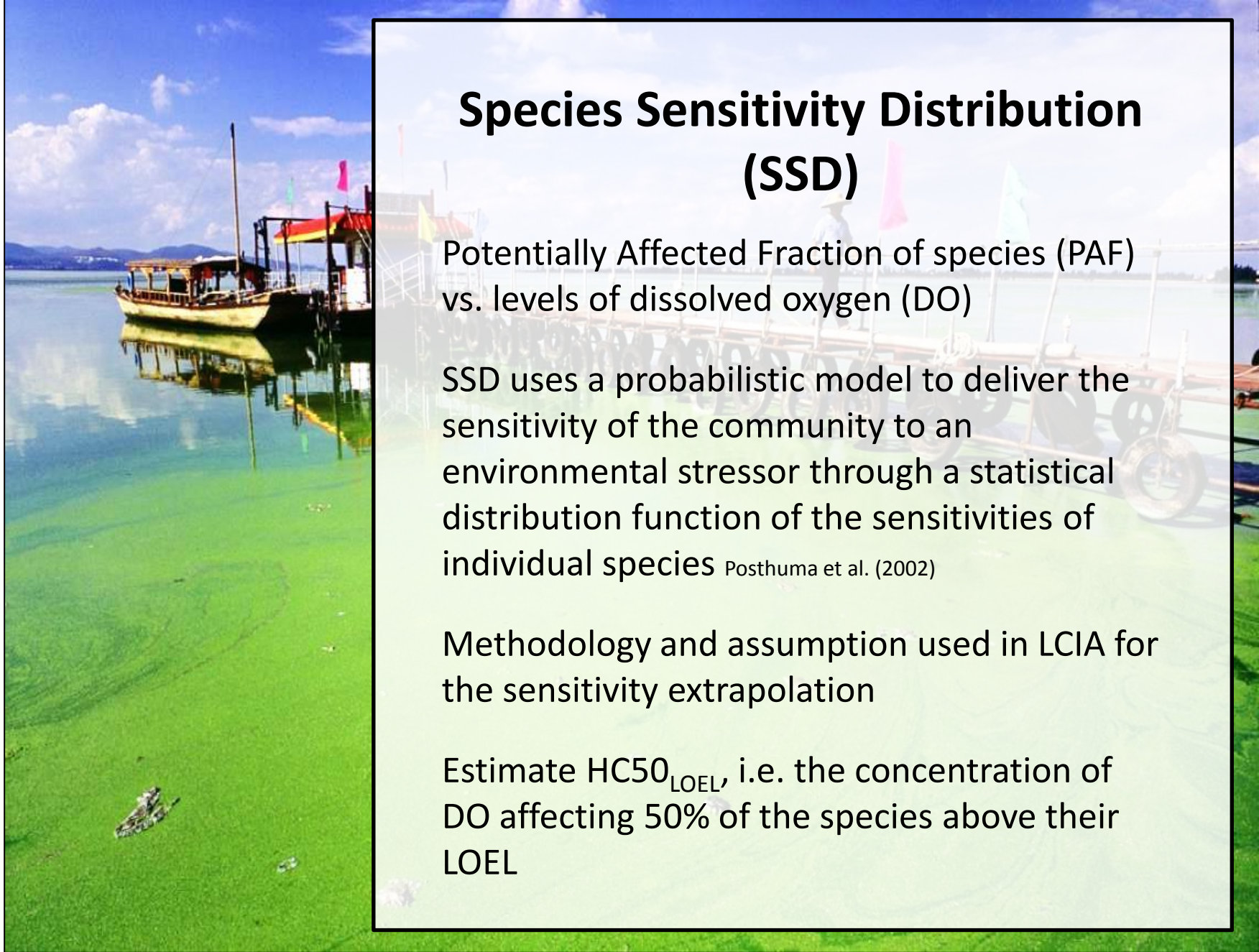
- 'World Register of Marine Species' (WoRMS) ([www.marinespecies.org](http://www.marinespecies.org))
- 'The Species 2000 & ITIS Catalogue of Life' ([www.catalogueoflife.org](http://www.catalogueoflife.org))
- 'Fishbase' ([www.fishbase.org](http://www.fishbase.org))
- 'FAO FishFinder' ([www.fao.org/fishery/fishfinder](http://www.fao.org/fishery/fishfinder))

Grouped into 5 climate zones:

- Polar, subpolar, temperate, subtropical, and tropical

Sample size and lack of representativeness prevented classification at finer spatial resolutions





# Species Sensitivity Distribution (SSD)

Potentially Affected Fraction of species (PAF) vs. levels of dissolved oxygen (DO)

SSD uses a probabilistic model to deliver the sensitivity of the community to an environmental stressor through a statistical distribution function of the sensitivities of individual species Posthuma et al. (2002)

Methodology and assumption used in LCIA for the sensitivity extrapolation

Estimate  $HC50_{LOEL}$ , i.e. the concentration of DO affecting 50% of the species above their LOEL



## Effect Factor (EF)

The EF expresses the change of effect ( $\Delta\text{PAF}$ ) due to a variation of the stressor intensity (depletion of DO, i.e.  $\Delta[\text{O}_2]$ )

$$\text{EF} = \frac{\Delta\text{PAF}}{\Delta[\text{O}_2]} = \frac{0.5}{\text{HC50}_{\text{LOEL}}}$$

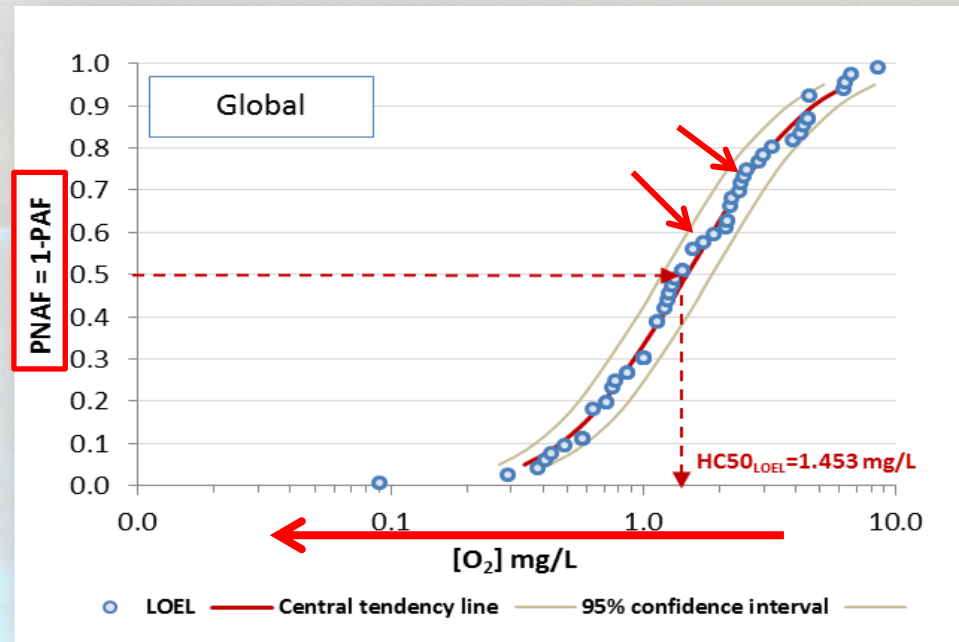
$\text{HC50}_{\text{LOEL}}$  can be obtained with SSD curves

$$\text{by } PNAF = \frac{1}{1 + e^{-(\log\text{HC50}_{\text{LOEL}} - \alpha)/\beta}}$$

or calculating the geometric mean of the LOEL data,  $\text{HC50}_{\text{LOEL}} = 10^{\text{avg}(\log\text{LOEL})}$

$[\text{PAF} \cdot \text{m}^3/\text{kgO}_2]$

# Preliminary results (I)



SSD curve of sensitivity to hypoxia (LOEL)

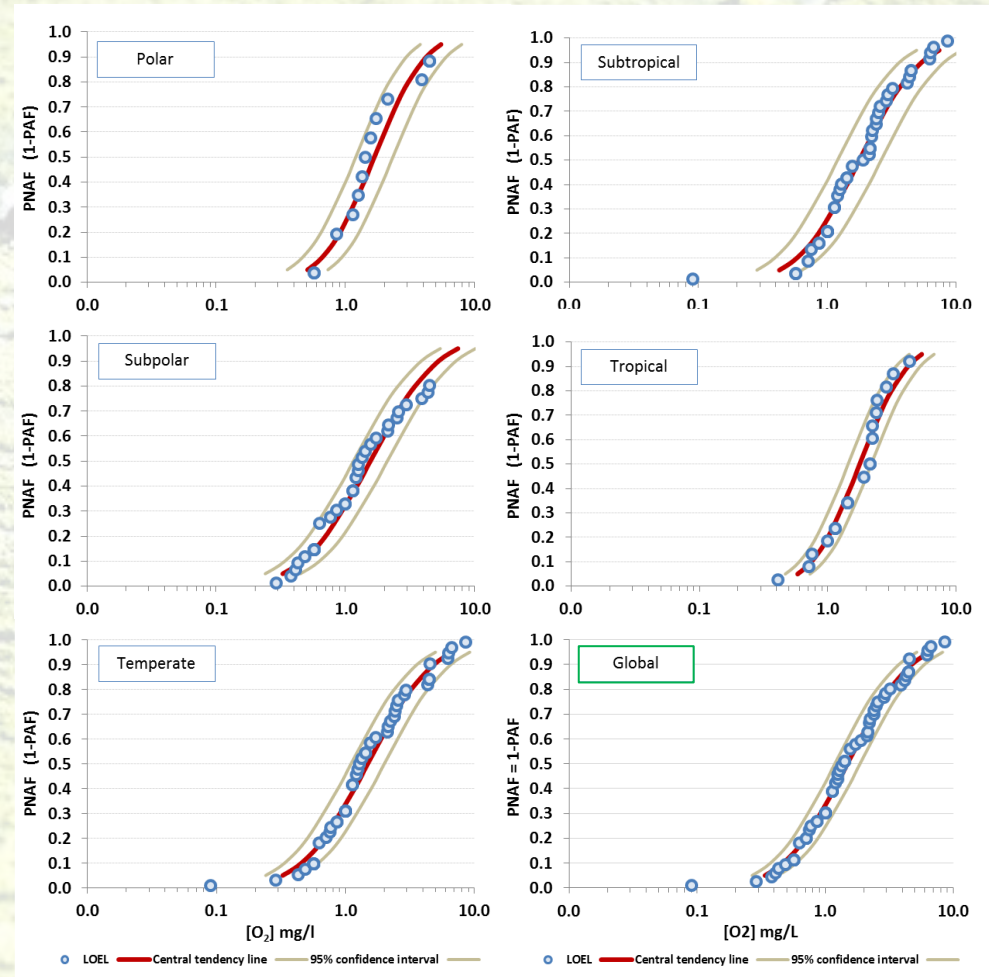
Estimation of e.g. the global default  
 $HC50_{LOEL} = 1.453 \text{ mgO}_2/\text{L}$  (n=58)

PNAF, Potentially Not Affected Fraction of species



# Preliminary results (II)

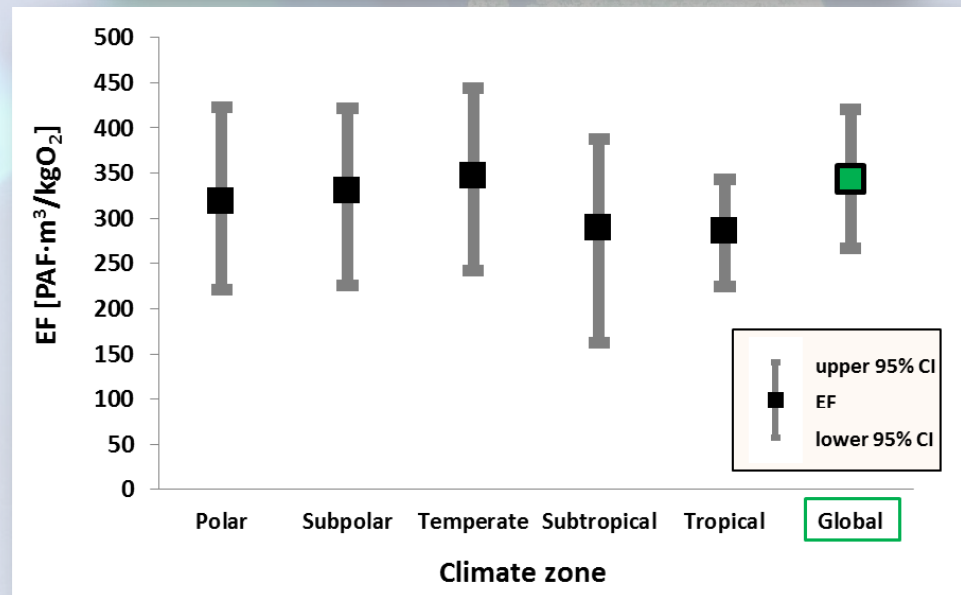
SSD curves for 5 climate zones and global default



# Preliminary results (III)

EF estimation for 5 climate zones and global default

Climate zone	<i>n taxa</i>	HC50 <sub>LOEL</sub>	EF	
		mgO <sub>2</sub> /L	lower CI	upper CI
Polar	13	<b>1.57</b>	215.18	<b>318.90</b>
Subpolar	38	<b>1.52</b>	237.51	<b>329.88</b>
Temperate	47	<b>1.44</b>	249.72	<b>347.07</b>
Subtropical	41	<b>1.73</b>	191.01	<b>289.48</b>
Tropical	19	<b>1.75</b>	229.18	<b>285.93</b>
Global	58	<b>1.45</b>	267.76	<b>344.10</b>





# Discussion (I)

## *Why such low spatial differentiation?*

Species per climate zone range from 13 (polar) to 47 (temperate) – too few?

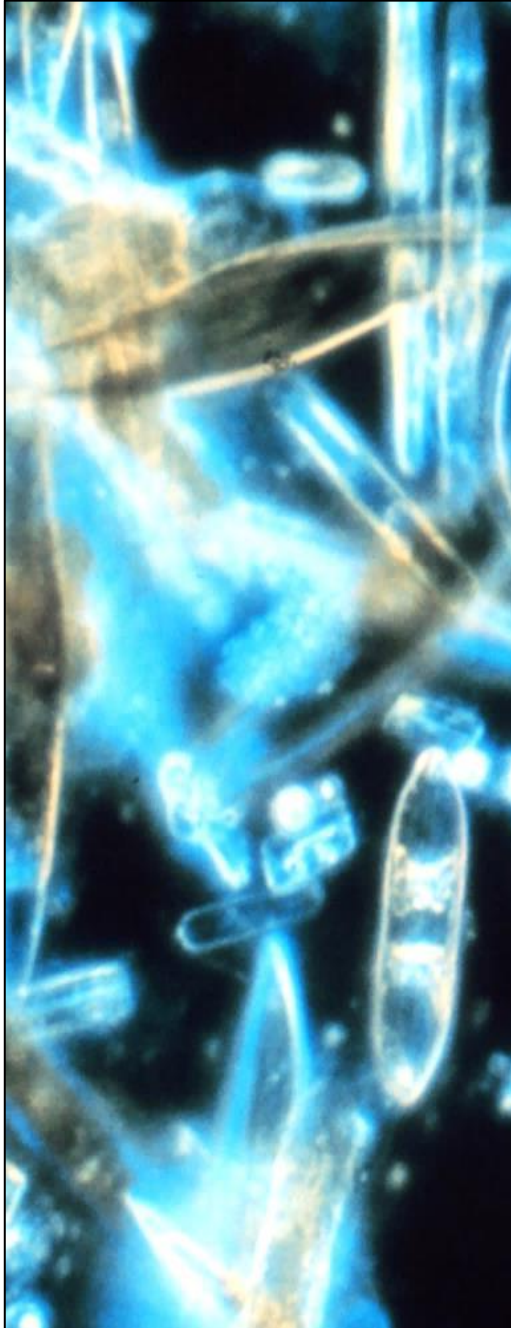
Species overlap:

- |                                             |               |             |
|---------------------------------------------|---------------|-------------|
| • 100% Polar also found in <u>Subpolar</u>  | <sup>25</sup> | <i>Test</i> |
| • 72% Subpolar found in <u>Temperate</u>    | <sup>9</sup>  | <i>-2%</i>  |
| • 72% <u>Temperate</u> found in Subtropical | <sup>13</sup> | <i>-25%</i> |
|                                             |               | <i>-44%</i> |

*Overlap = high contribution from sensitive species*

Spatial resolution at climate zone level – is it too low?

Is there actually a natural differentiation of sensitivity? (*water Temp, metabolism, solubility*)



## Discussion (II)

### *Issues with data representativeness?*

Test-related errors – experimental methods, endpoints classification or identification

Biased selection for ‘preferred’ species or taxonomic groups:

- Easier to rear/maintain
- Show visible (easy) endpoints
- Commercial value
- Locally available

### *Geographical representativeness and species coverage*

e.g. Mediterranean Sea (18/170) – LOEL for only 11% of potentially occurring species (IUCN db)



## Preliminary conclusions

Method based on SSD and sensitivity to oxygen depletion was proposed

Applicable in LCIA as an EF for the marine eutrophication indicator

Contribute to a CF expressing the damage to ecosystem quality

The global default EF can be used for any region

Low spatial differentiation obtained mainly due to a short dataset and some concerns about representativeness

To increase resolution → expand the dataset



# Thank you all for your attention

**Quantitative Sustainability Assessment**  
Department of Management Engineering

[nmdc@dtu.dk](mailto:nmdc@dtu.dk) - [www.qsa.man.dtu.dk](http://www.qsa.man.dtu.dk)

